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Differential Growth in Purslane Species Grown in Two Different Seasons

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Abstract

With the growth of world population, climate changes and the food safety will be a problem. *Portulaca* is a wild edible plant adapted to warm climate and resistant to drought. The aim of this work was to evaluate 18 accessions of *Portulaca* species under two agro-climatic conditions. The experiment was conducted in an entirely randomized design, with 3 replicates, following the factorial scheme 2 seasons x 18 accessions, based on nine quantitative traits the interaction between seasons and accessions was significant for number of leaves ($p \leq 0.01$). It is possible to observe that all the genotypes evaluated showed stability, except for the genotype PH01, which presented a smaller number of leaves in winter season. The accessions PU02 and PU10 presented major plant height and leaves measurements. The accessions PU11, PU03, PU07 and PG02 presented greater number of leaves and shows stability between seasons. These belong to *P. umbraticola* and *P. grandiflora* and were superior to the *P. oleracea* species. They should be used in hybridization program in order to insert desirable genes to produce new productive vegetable crop, being new species options in order to replace conventional plants.

Keywords: agro-climatic conditions; morphological traits; *Portulaca umbraticola*; *Portulaca grandiflora*; *Portulaca halimoide*; *Portulaca werdermanni*; *Portulaca oleracea*; *Portulaca amilis*

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1. Introduction

The projected world population is 10 billion habitants by the year 2050, increasing food demand. The majority of world's contemporary cropland has yields well below their potential, and the agricultural expansion has serious long-term implications for the ecosystems [1].

We often do not explore the full food potential available in local biodiversity, being restricted to a small group of options. Wild Edible Plants (WEP) or Nonconventional edible plants (NCEP) can enrich and enhance culinary preparations in several ways [2,3]. Employs more efficient nutrient use worldwide provides a promising path to more environmentally sustainable agricultural intensification and more equitable global food supplies [1].

Purslane belongs to *Portulaca* genus and is widely known by its ornamental use due to their range of flower's color [4,5]. Beside this, it is a valuable WEP species, spread worldwide, and is a promising alternative to substitute conventional crops in harsh conditions due to its resilience to adverse conditions [3,6,7]. Through extreme weather, climate change will disturb food security and crop production [8].

Purslane has in its composition all the essential minerals, vitamins and proteins, in addition to having the highest vitamin content among green leafy vegetables [9]. Phytochemical studies have shown that purslane is one of the richest terrestrial sources of ω-3 and ω-6 fatty acids [10,11]. Purslane is a rich source of ascorbic acid, tocopherols, glutathione and β-carotene, suggesting its nutraceutical

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potential, it is also an important source of specialized metabolites such as alkaloids, catecholamines, phenolic acids, anthocyanins, flavonoids, lignans, terpenoids and betalains [6]. It makes purslane a potential new source of nutritious food for both humans and animals [11]. These scientific reports of its chemical compounds shown that this common weed has potential use as nutraceutical and pharmacological vegetable, making it one of the potentially important crop for the future [6,12].

Besides this, purslane is also a source of features of direct importance to the agricultural such as phytoremediation, allelopathy, and tolerance to biotic and abiotic stress [7,13,14].

In several countries Purslane is seen only as a weed and its cultivation as a food crop is little exploited [3]. This cosmopolitan genus is widespread in Brazil where it is consumed for ornamental purposes and as NCEP [13,15]. Few studies have focused on cultivation and domestication of purslane and efforts must be taken to exploit purslane genetic variability for local agronomic programs based on the availability and suitability of *Portulac*a accessions/species [4].

Genetic variations are crucial in plant breeding programs to produce new superior cultivars and better selection efficiency [16]. It can be determined through genealogical analysis using a variety of methods, including molecular markers, protein markers and morphological characteristics [17]. Quantitative traits, such as yield and yield components, of many crops are affected by Genotypic (G) x Environmental (E) interactions which are a concern to plant breeders [18]. G x E interactions reduce the correlation between genotype and phenotype and may contribute to the instability of accessions when grown in different environments, planting dates and cultural practices. Knowing how these factors impact plant growth and development would reduce yield losses. As far as we concern only one study was made to determine the effect of planting date and its interaction with different genotypes on purslane yield and yield components [19].

This study was conducted to give more accurate investigation about the performance of 18 different purslane parental lines in two different seasons (planting date) in order to identify the most stable accession for better exploitation in breeding programs.

2. Materials and Methods

2.1. Plant Material, Cultivation, and Experimental Location

Eighteen accessions of *Portulaca* spp. belonging to the Vegetable Germplasm Bank of the aforementioned institution were used (Table 1). The accessions were propagated through cuttings. Three cuttings of each accession were arranged in different pots with 3.3L of capacity filled with coconut fiber substrate, previously autoclaved.

Table 1. Acession name and species of 18 accessions evaluated in this study.

Acession name	Species
PH01	*Portulaca halimoides*
PG08	*Portulaca grandiflora*
PU01	*Portulaca umbraticola*
PU11	*Portulaca umbraticola*
PU05	*Portulaca umbraticola*
PU02	*Portulaca umbraticola*
PU03	*Portulaca umbraticola*
PU06	*Portulaca umbraticola*
PU07	*Portulaca umbraticola*
PU08	*Portulaca umbraticola*
PU09	*Portulaca umbraticola*
PU10	*Portulaca umbraticola*
PG 01	*Portulaca grandiflora*

PG02	*Portulaca grandiflora*
PW 1	*Portulaca werdermanni*
PO01	*Portulaca oleracea*
PA01	*Portulaca amilis*
PO02	*Portulaca oleracea*

The experiment was carried out in a greenhouse at the Laboratory of Biotechnology and Plant Breeding of the Center of Agricultural Sciences of the Federal University of Paraíba, located on Areia City, Paraíba State, northeast of Brazil (6°58′18″S 35°43′16″W) at an altitude of 510 m above the ocean level.

Two experiments were carried out. The first one, on summer, from 10/17/2022 to 01/23/2023), and the second one on winter, from 05/01/2023 to 08/07/2023.

Weather conditions among the eight months of experiments were collected in Instituto Nacional de Meteorologia [20] (Table 2).

Table 2. Weather conditions of conducted experiments, during two seasons.

		Summer				Winter			
		Oct	Nov	Dec	Jan	May	Jun	Jul	Aug
Temperature (ºC)	Max	23.2	23.7	24.1	23.6	23.3	21.7	21.6	21.6
	Min	22.0	22.5	22.9	22.5	22.4	21.0	20.7	20.7
	Average	22.6	23.0	23.5	23.0	22.8	21.0	21.0	21.0
	SD	2.66	2.93	2.97	2.68	2.10	1.89	2.07	2.51
	SE	0.008	0.004	0.004	0.01	0.002	0.002	0.002	0.014
Moisture (%)	Max	83.0	83.6	81.9	85.9	89.0	92.7	89.5	88.2
	Min	78.0	78.7	76.5	81.0	86.0	90.0	85.6	84.3
	Average	80.0	81.2	79.2	83.0	88.0	91.4	87.5	86.3
	SD	15.15	16.242	16.91	14.60	10.65	8.886	10.83	12.28
	SE	0.048	0.022	0.023	0.07	0.014	0.012	0.015	0.073
Precipitation (mm)	Average	0.0059	0.06	0.034	0.204	0.163	0.411	0.158	0.135
	SD	0.061	0.355	0.277	1.110	0.899	1.125	0.877	0.450
	SE	0.0002	0.0005	0.0003	0.005	0.0012	0.00015	0.0012	0.0026

SD = Standard Deviation; SE = Standard Error.

2.2. Morpho-Agronomic Characterization and Statistical Analysis

The characterization was made at flowering stage, based on nine quantitative traits: caopy width (cm), plant height (cm), stem diameter at the base (cm), internode distance (cm), leaf width (cm), leaf length (cm), flower diameter (cm), number of leaves and number of branches. All data were obtained using a digital caliper (LOTUS PLUS®), graduated ruler and counting. The characterization was made

45 days from sowing. They were submitted to the best agronomic practices including irrigation, fertilization, and application of pesticides for pest and plant disease control. Fertilizer was supplied once a weekly in the dosages recommended for vegetables. The plants received daily water supply until they reached field capacity in the pots, through micro-sprinklers installed on the greenhouse benches. They were also in full sunlight for the location 6°58'18. 7 "S 35°43'15. 0 "W.

The experimental design was completely randomized in a 2 x 18 factorial scheme (2 seasons and 18 accessions), with three replicates. The obtained data were subjected to a model III analysis of variance [21] with subsequent grouping of means by Skott-Knott test ($p \leq 0.01$). All statistical analyses were performed in the GENES Software [22].

3. Results

3.1. Analysis of Variance

There were no significant differences for interaction between seasons x accessions factors for all evaluated traits ($p \leq 0.01$), except for number of leaves. Accessions factor showed significance for all the evaluated traits ($p \leq 0.01$). On the other hand, season factor presented significance for all traits, except for internode distance, leaf width, flower diameter and number of leaves (Table 3).

Table 3. Summary of analysis of variance for nine quantitative variables of 18 accessions of Portulaca spp.

	Mean Square				
S. V	**CW**	**PH**	**SD**	**ID**	**LW**
Seasons (S)	1,634.889**	316.555**	0.243**	0.5508 ns	0.09907 ns
Accessions (A)	1,228.059**	322.702**	0.792**	0.45424**	1.31819 **
S x A	186.886ns	44.863 ns	0.1423 ns	0.12455 ns	0.05214 ns
S. V	**LL**	**FD**	**NL**	**NB**	-
Seasons (S)	1.224**	0.263 ns	301255.703**	1533.787**	-
Accessions (A)	2.689**	8.1964**	539,482.22 ns	717.397**	-
S x A	0.153 ns	0.160 ns	159.184.76**	151.100 ns	-

**Significant by F test ($p \leq 0.01$). ns: not significant. S.V – Source of variation; S x A – season x accession interaction. CW - Canopy width; PH – Plant height; SD - Stem diameter; ID - Internode distance; LW - Leaf width; LL - Leaf length; FD - Flower diameter; NL- Number of leaves; NB – Number of branches.

3.2. Unfolding Seasons x Accessions Interaction

Unfolding seasons x accessions interaction for number of leaves, it was possible to group the accessions into three classes in summer and two classes in winter (Table 4). The accession PH1 presented the highest leaves number and the accessions PG01, PW1, PO01 and PO02 presented the lowest averages of leaves number. In winter, in addition to the genotypes PG01, PW1, PO01 and PO02, the genotype PA01 presented lower averages and the others presented higher average values. Analyzing the seasons within the accessions, it was possible to observe that all the evaluated accessions remained stable except for the genotype PH01, which presented smaller number of leaves in this season (Table 4).

Table 4. Comparison of means for number of leaves between two seasons and 18 accessions.

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Accessions	Number of leaves	
	Summer	Winter
PH01	2,059.333 Aa	830.333 Ba
PG08	625.333 Ab	698.666 Aa
PU01	851.000 Ab	645.333 Aa
PU11	816.333 Ab	1,078.666 Aa
PU05	657.333 Ab	664.000 Aa
PU02	631.666 Ab	889.000 Aa
PU03	975.666 Ab	851.666 Aa
PU06	796.333 Ab	854.000 Aa
PU07	871.333 Ab	884.333 Aa
PU08	836.000 Ab	762.333 Aa
PU09	740.666 Ab	638.000 Aa
PU10	719.666 Ab	655.666 Aa
PG 01	325.666 Ac	386.000 Ab
PG02	1,031.000 Ab	710.333 Aa
PW 1	424.333 Ac	247.666 Ab
PO01	285.666 Ac	84.333 Ab
PA01	574.666 Ab	300.666 Ab
PO02	197.333 Ac	337.000 Ab

Means followed by the same capital letters, in line, and lowercase letters, in column, do not differ statistically from each other according to the Scott-Knot test ($p \leq 0.01$).

3.3. Effect of Accession Factor

It was possible to group the accessions from two to five distinct classes for the analyzed variables (Table 5).

Table 5. Comparison of eight quantitative variables among 18 purslane accessions.

Accessions	CW (cm)	PH (cm)	SD (cm)	ID (cm)
PH 1	32.816 b	22.65 c	0.314 b	1.014 b
PG08	48.00 a	27.833 c	0.455 b	1.039 b
PU01	57.583 a	34.466 b	0.719 a	1.411 a
PU11	56.233 a	33.633 b	0.611 a	1.376 a
PU05	55.450 a	34.466 b	0.634 a	1.343 a
PU02	66.40 a	45.216 a	0.643 a	1.390 a
PU03	52.15 a	32.783 b	0.652 a	1.229 a
PU06	45.133 a	25.516 c	0.607 a	1.178 a
PU07	53.566 a	34.066 b	0.678 a	1.311 a
PU08	48.233 a	29.55 b	0.675 a	1.551 a
PU09	52.633 a	31.516 b	0.638 a	1.375 a
PU10	59.083 a	41.166 a	0.776 a	1.278 a
PG 01	24.366 b	23.333 c	0.425 b	0.701 b
PG02	52.75 a	33.55 b	0.672 a	1.136 a
PW 1	27.566 b	24.966 c	0.591 a	0.866 b

PO01	22.15 b	24.383 c	0.535 b	0.639 b
PA01	23.083 b	14.416 d	0.453b	0.919 b
PO02	28.033 b	23.433 c	0.569 a	1.608 a

Accessions	LW (cm)	LL (cm)	FD (cm)	NB
PH 1	0.224 d	1.045 d	0.599 e	44.166 a
PG08	0.316 d	2.217 b	2.884 b	24.333 b
PU01	1.588 a	2.967 a	2.624 b	35.500 a
PU11	1.421 a	2.715 a	2.458 b	43.00 a
PU05	1.361 a	2.451 b	1.966 c	30.333 a
PU02	1.191 b	2.442 b	2.376 b	35.333 a
PU03	1.152 b	2.175 b	2.595 b	47.00 a
PU06	1.303 a	2.885 a	2.479 b	34.833 a
PU07	1.443 a	2.677 a	2.314 b	36.833 a
PU08	1.455 a	2.643 a	2.557 b	39.666 a
PU09	1.462 a	2.842 a	2.736 b	35.666 a
PU10	1.364 a	3.039 a	2.616 b	35.833 a
PG 01	0.253 d	1.203 d	1.822 c	14.333 b
PG02	1.001 b	2.010 b	2.442 b	47.00 a
PW 1	0.549 c	2.422 b	5.791 a	7.833 b
PO01	0.608 c	1.079 d	0.693 e	17.333 b
PA01	0.588 c	1.514 c	1.149 d	31.500 a
PO02	0.945 b	1.497 c	0.582 e	29.000 a

Averages followed by the same lowercase letters, in the column, do not differ statistically from each other by the Scott-Knot test ($p \leq 0.01$). CW - Canopy width; PH – Plant height; SD - Stem diameter; ID - Internode distance; LW - Leaf width; LL - Leaf length; FD - Flower diameter; NB – Number of branches.

The accessions were grouped into two distinct classes for canopy width. Accessions PH01, PG01, PW1, PO01, PA01 and PO02 presented the lowest averages for this traits and the other genotypes obtained the highest averages (Table 5).

Regarding the plant height, the accessions were jointed into four distinct classes. PU02 and PU10 presented the highest average, and the other ones presented lower averages (Table 4).

The stem diameter presented two distinct classes, and the accessions PH01, PG08, PG01, PO01 and PA01 presented the smallest average values (Table 4).

The internode distance was divided into two classes. The lowest averages values were found in the accessions PH01, PG08, PG01, PW01, PO01, and PA01 (Table 4).

The accessions were grouped into four classes for leaf width. PH1, PG08, and PG01 presented the lowest means values. On the other hand PU01, PU11, PU05, PU06, PU07, PU08, PU09 e PU10 presented the largest leaves. (Table 5)

The flower diameter presents the major number of classes, and accession PW01 showed the highest average value for this trait. PW01 accession flowers were twice bigger than the others evaluated accessions (Table 5).

For the number of branches characteristic two groups were formed. The group with major number of branches reaches from 29 to 47 branches. The group with minor number of branches presented from 7.833 to 24.33 (Table 5).

3.4. Effect of Seasons

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All evaluated characteristics presented the highest averages in the summer, except leaf length (Table 6).

Table 6. Means values for eight evaluated traits of Portulaca spp., into two different seasons.

Means values				
Seasons	**CW (cm)**	**PH (cm)**	**SD (cm)**	**ID (com)**
Summer	48.625 a	31.542 a	0.638 a	1.209 a
Winter	40.844 b	28.118 b	0.543 b	1.164 a
Seasons	**LW (cm)**	**LL (cm)**	**FD (cm)**	**NB**
Summer	0.984 a	2.106 b	2.211 a	36.518 a
Winter	1.044 a	2.319 a	2.039 a	28.981 b

Averages followed by the same lowercase letters, in the column, do not differ statistically from each other by the Scott-Knot test ($p \leq 0.01$). CW - Canopy width; PH – Plant height; SD - Stem diameter; ID - Internode distance; LW - Leaf width; LL - Leaf length; FD - Flower diameter; NB – Number of branches.

4. Discussion

4.1. Unfolding Seasons x Accessions Interaction

Purslane yield can vary with cropping system, the edaphoclimatic conditions, and input applied by the growers [3,11,23]. The highly significant SxA interaction for number of leaves presented in this work, suggesting a differential response of genotypes (accessions) across testing environments (seasons). Significant interaction between planting date and genotypes for yield and yield components were found in different accessions of *Portulaca* spp. [19]. On the other hand, planting date as an isolated factor had no significant direct effect over the evaluated traits (yield, height, branches and nodes per plant and flowering date). Differential yield were found among six purslane genotypes highlighting the importance of selecting a proper ecotype for food products, since the fresh leaves and stems are the consumed parts [24]. Among all studied accessions, PH01 presented major number of leaves but it did not show stability between the cultivation seasons. On the other hand PU11, PU03, PU07 (*P. umbraticola*) and PG02 (*P. grandiflora*) were stable over the seasons and produce a considerable number of leaves varying from 710.33 to 1,078.66. These accessions had a greater number of leaves than the accessions belonging to *P. olearacea*, such as PO01 e PO02, which is the most cultivated and studied species as a non-conventional edible plant (NCEP) or a wild edible plant (WEP) [3]. Crossbreeding between these two species will enable new cultivars of interesting traits for ornamental purposes. Our findings enable us to extend their cross to achieve vegetable production as well [25].

4.2. Accession Factor Variation

Regarding canopy width the accessions PH01, PG01, PW1, PO01, PA01 and PO02 presented the lowest averages from 22.15 to 32.81 cm. The other genotypes obtained the highest averages varying from 45.13 to 66.40 cm. The majority of scientific works about purslane did not evaluate this trait *[11,23,25–32*]. The range of canopy width measurements reported in this work was greater then the values for P. umbraticola (33.0 to 65.0cm) (Souza et al. 2024). It is expected since we worked with six different species of Portulaca (Table 1). It is important highlighted it is important to evaluate canopy width and plant height since purslane is a leafy vegetable commercialized in bunches.

The highest accessions ranges from 41.16 to 45.2cm, while the lowest one was 14.41cm high. Two more groups were formed in between these extreme groups: one with height from 29.55 to 34.466 cm, and the other ranges 22.65 to 25.51cm. In a study with 20 accessions of P. oleracea inferior heights (21.13 – 34.3cm) were found [11]. Other study about 45 accessions of P. oleracea with heights varying from 20.6 to 40.8cm. [23] The same behavior was observed in five commercial cultivars of purslane

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(8.92 – 19.55cm) [31]. Other authors evaluated the plant height of cultivated and wild purslane (P. oleracea) in five different harvests and soilless substrates showing similar results from plant height for the first harvest independent of the used substrate [29]. The values of plant height were superior to our results only when the plants were older, from second to fifth harvest. Great variability in plant height within common purslane cultivars (P. oleracea) (17 -70cm), were presented on 45 days after sowing [28]. The finds of these authors demonstrate the existence of genetic diversity within species corroborating with our data.

The group with major values of stem diameter, from 0.569 to 0.766cm, were superior of those described to P. oleracea cultivated in pots (0.224 – 0.321cm) [11], (0.212 – 0.380cm) [23], and to P. umbraticola cultivated in pots (0.28 – 0.38cm) [15]. On the other hand, P. oleracea cultivated in field had thicker stem (0.75 – 1.9cm) [17]. Thicker stems provide better sustenance for the plant and facilitate plant vegetative propagation by cuttings [15].

Internode distance ranges from 0.639 to 1.608cm. These values were bigger than the values of P. oleracea [11Alam et al. 2014a,b, 28). On the other hand, no significant differences were found in P. umbraticola for this trait [15].

The highest leaf width and length, (1.303 - 1.588cm) and (2.643 - 3.039cm), respectively, were smaller than the values found in P. oleracea (1.15 - 3.46cm) width (2.28-6.65cm) length [32]. The leaf length presented in this work was bigger than those found in different genotypes of Portulaca sp. (1.45 - 1.57cm) [31] and P. umbraticola (0.864 - 1.38) [15]. The leaf properties will be more effective in genetic improvement programs. In the same way other authors indicate long leaf blade as a characteristic for an ideal or ideotype genotype in purslane [26].

Flower diameter was the character with major number of classes and ranges from 0.582 to 5.791cm. In an ornamental plant-breeding program, it is important to select accessions with larger flowers [33]. In this way the accession PW01 should be used as genitor to insert this trait in a recurrent genitor since it shows flowers twice bigger than the others evaluated accessions (Table 5).

The number of branches varied from 7.833 to 47 branches. These numbers were higher than the values reported to P. umbraticola [7–11,15]. Inferior values of number of branches per plant (9.89 – 13.52) were reported in other research [31]. On the other hand, No significance for number of branches were found in P. oleracea [17]. The number of branches is an important trait to evaluate, such as canopy width and plant height, since purslane is a leafy vegetable commercialized in bunches.

4.3. Effect of Seasons Factor Variation

Portulaca species developed better all evaluated traits on summer, except leaf length. The summer season was characterized by higher temperatures and lower moisture and precipitation (Table 2). Increased temperature stimulate purslane growth as observed in this work [26].

5. Conclusions

In general, the results of this study revealed significant variation in morphological traits among and within *Portulaca* species/accessions.

The accessions PU02 and PU10 presented major plant height and leaves measurements. On the other hand accessions PU11, PU03, PU07 and PG02 presented greater number of leaves and shows stability between the two seasons of production. These outstanding accessions, belonged to *P. umbraticola* and *P. grandiflora*, were superior to the *P.oleracea* species. They should be used in the hybridization program in a recurrent selection scheme in order to insert desirable genes to produce new productive vegetable crop, being new species options in order to replace conventional plants.

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